Status of the NASA Allsky Camera Network

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In the Beginning...

- There were visual observers (and still are)
- Data limited to radiants and rough estimates of speed and brightness
- Can get very cold during winter nights

FIG. 3-3. Modern visual meteor observing at Springhill Meteor Observatory near Ottawa. Warm air is supplied to the individual compartments.

Photographic Observations

Wide field

Meteorite Observation and Recording Program (MORP)

All sky

Modra Observatory

- All sky systems are nice because only 1 camera is needed per station

Super Schmidt Cameras

- First employed in the 1940's
- Detected bright meteors (magnitudes > +3)
- Large FOV
- Multiple stations and use of rotating shutter enabled location, speed, and orbit determinations

- Much of what we know is based on data taken with these systems

Super Schmidt camera (Haleakala)

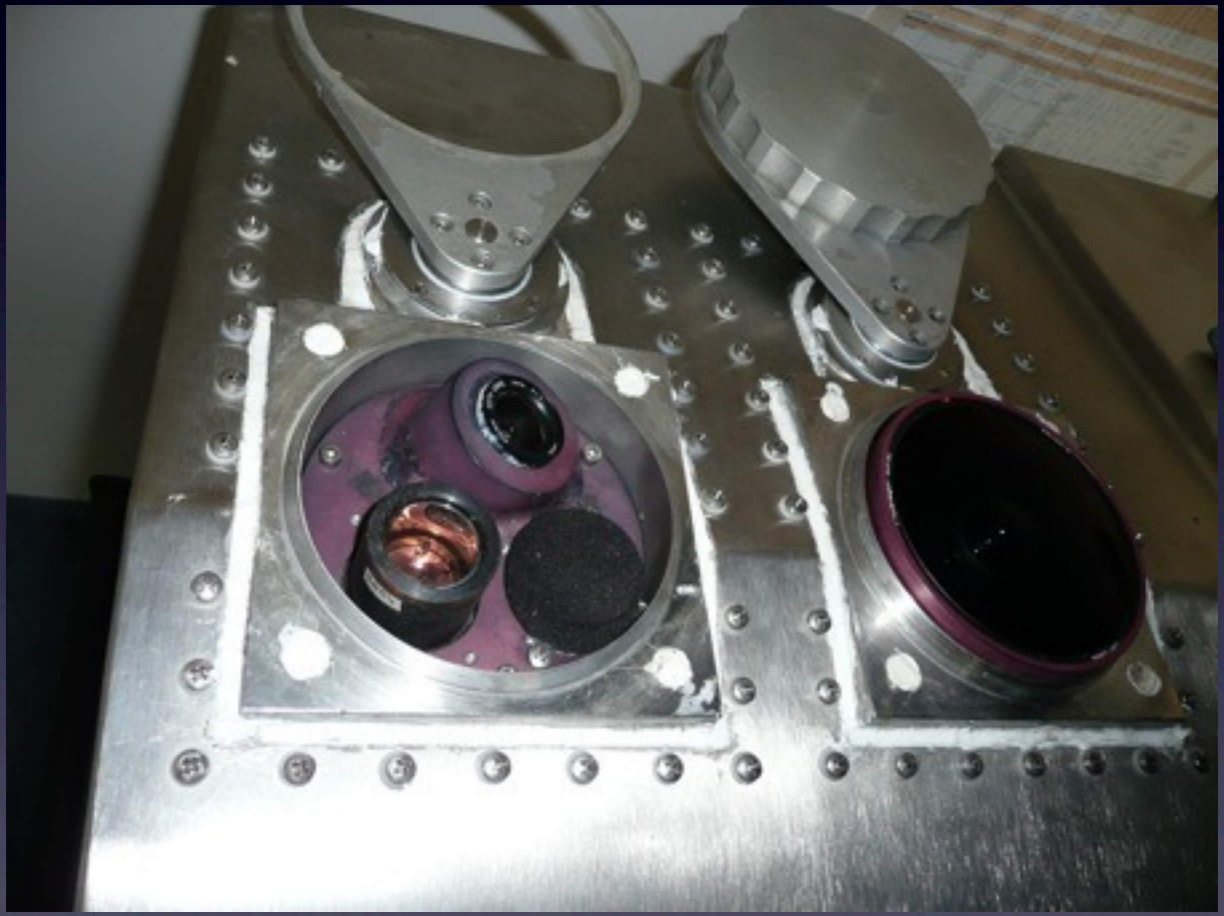
- The advent of fast, wide field photographic systems led to the creation of the first meteor networks
- European Fireball Network began in 1958 in Germany and Czechoslovakia
- The Prairie Network began in 1964 in the U.S. Funding was terminated in 1975
- MORP began in Canada in 1968. Its 12 stations used Super-Komura cameras. Funding discontinued in 1985

- Th s es (at least in part)

- Funding discontinued due to lack of scienti interest and disappointing number of finds (1 each for Prairie and MORP)
- Only European network remains operating today

Photographic Advantages

- Large dynamic range
    - Good photometry
- High resolution
    - Precise astrometry
- Can be automated to <u>some</u> degree



Czech system

Video Observations

- Largely pioneered by Clifton and Naumann in the 1960's at MSFC (Meteor Physics Branch)
- Advantages:
    - 100x better sensitivity over Super Schmidt cameras
    - 30 fps rate gives better temporal resolution than rotating shutter
    - Unrivaled temporal accuracy thru GPS time stamps
- Disadvantages:
    - Limited resolution compared to photographic
    - Limited dynamic range (most systems are 8 bit)

The Sandia Sentinel Systems

- Sentinel I (1998) - “look down” system with hardware meteor detection. 6 second buffer, parallel connection to computer (Moooo)
- Sentinel II (2004) - conventional all sky with hardware detection. USB connection to computer
- Sentinel III (2007) - all sky system with software detection

Camera: Hi-Cam HB-710E
Lens: Rainbow L163VDC4 1.6-3.4mm f/1.4 lens

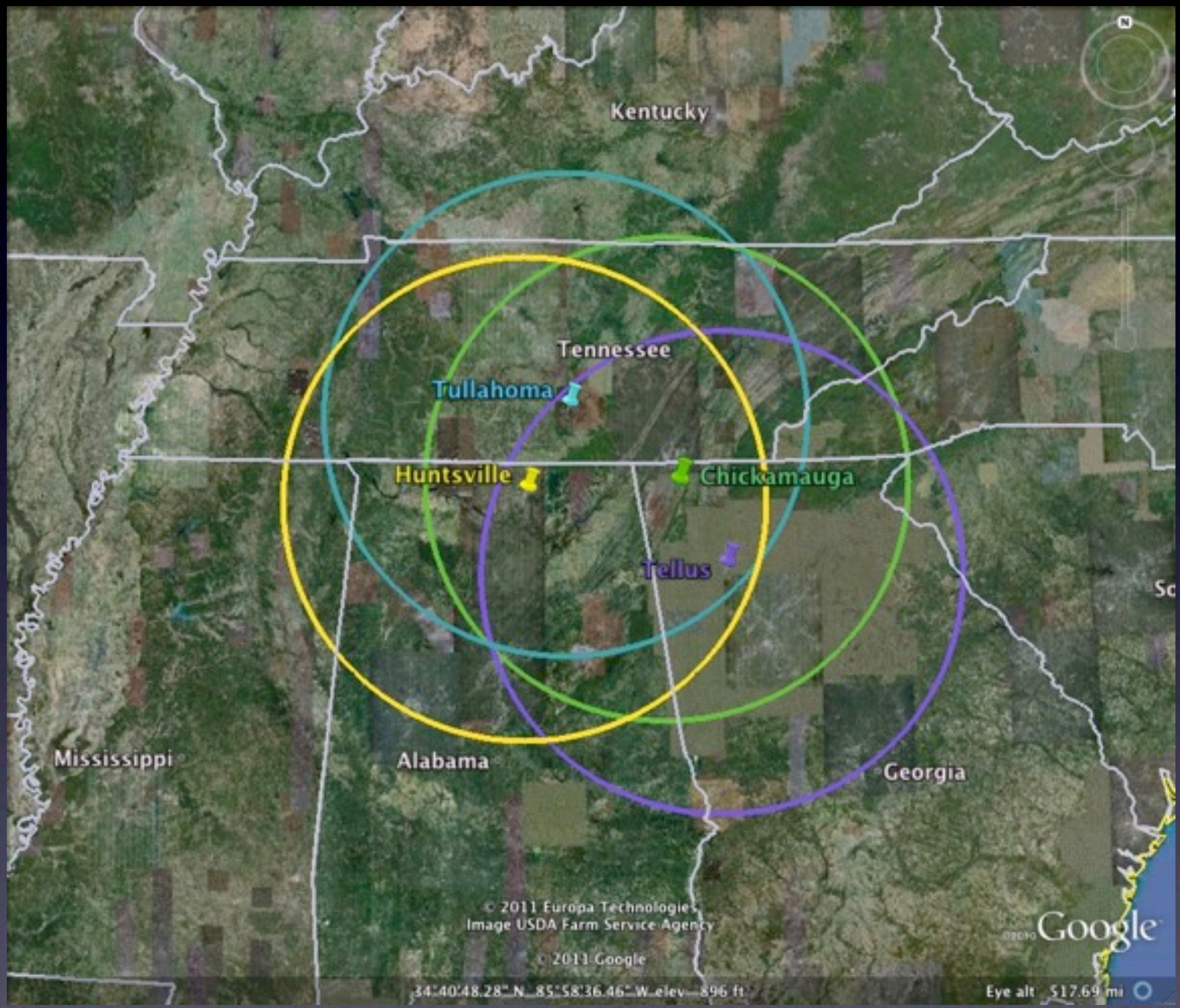
Current Fireball Networks

Name	System Type	Start Year	Reference
European Network	Photographic	1951	Oberst et al (1998)
Japan Fireball Network	Video	1977	Shiba et al (1998)
Sandia All-sky Network	Video	1997	
Spanish Meteor Network	CCD/Video	1997	Trigo-Rodriguez et al (2008)
Denver Museum Fireball Network	Video	2001	Sullivan and Klebe (2004)
Southern Ontario Meteor Network	CCD/Video	2004	Weryk et al (2008)
Desert Fireball Network	Photographic	2004	Spurny and Borovicka (2006)
Polish Fireball Network	Video	2004	Olech et al (2006)

Goals of the NASA Network

- Establish the speed distribution of cm size meteoroids
- Determine which sporadic sources produce large particles
- Determine (low precision) orbits for bright meteors
- Attempt to discover the size at which showers begin to dominate the meteoroid flux
- Monitor the activity of major meteor showers
- Assist in the location of meteorite falls

Station Locations



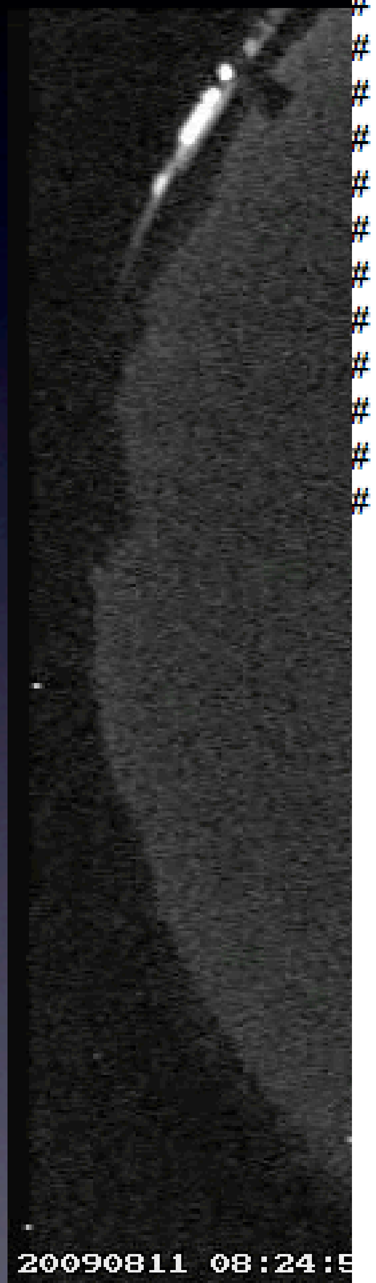
- 11 more to install!

Automated Lunar and Meteor Observatory (ALaMO)

Station Components

- All-sky Camera
  - Low light level video camera
  - All sky (fish eye) lense
  - heater/fan to prevent dewing
- Computer running ASGARD (**A**ll **S**ky and **G**uided **A**utomatic **R**eal-time **D**etection) software
- GPS
- Uninterruptible Power Supply (UPS)
- Internet connection

Detection

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#      unix : 1249979091.297046
#       ntp : LOCK 62141 181788 31681
#       seq : 43288344
#       mul : 0 [A]
#      site : 02
#    latlon : 34.8535 -85.3143 246.0
#      text : C3PO
#     label :
#     plate : 20090724-094001-02-aut-calib-ID
#      geom : 640 480
#    reject : 0
#
#  fr    time   sum      seq       cx       cy      th      phi     lsp    mag  flag
   30  -0.500  4499 43288329  300.265  308.405  24.895  -75.082   -7.15  -7.15  0000
   31  -0.467  5283 43288330  301.501  310.025  25.186  -76.129   -7.54  -7.54  0000
   32  -0.434  4890 43288331  301.857  314.106  26.190  -77.110   -8.12  -8.12  0000
   33  -0.400  5619 43288332  303.022  316.712  26.756  -78.211   -8.48  -8.48  0000
   34  -0.367  7861 43288333  303.941  320.176  27.574  -79.268   -8.62  -8.62  0000
   35  -0.334  7651 43288334  305.163  322.512  28.087  -80.263   -8.82  -8.82  0000
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   41  -0.133  7929 43288340  312.432  342.882  33.039  -86.010   -9.33  -9.33  0000
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   44  -0.033 13750 43288343  315.998  356.506  36.573  -88.429  -10.22 -10.22  0000
   45   0.000 14263 43288344  316.409  358.491  37.099  -88.699  -10.62 -10.62  0000
   46   0.033 11660 43288345  318.995  360.889  37.673  -89.865  -10.24 -10.24  0000
   47   0.067 12812 43288346  318.587  366.500  39.220  -89.918  -10.87 -10.87  0000
   48   0.100 11156 43288347  321.343  368.218  39.623  -91.050  -10.04 -10.04  0000
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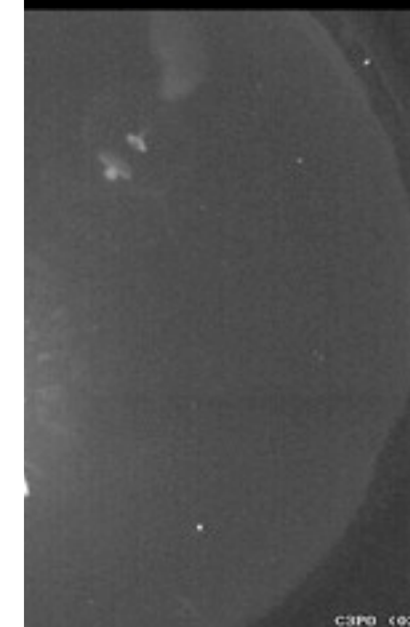
```

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-ID

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.106  26.190  -77.110   -8.12  -8.12  0000
.712  26.756  -78.211   -8.48  -8.48  0000
.176  27.574  -79.268   -8.62  -8.62  0000
.512  28.087  -80.263   -8.82  -8.82  0000
.347  29.011  -81.338   -8.98  -8.98  0000
.721  29.554  -82.238   -9.07  -9.07  0000
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.717  34.011  -86.882   -9.45  -9.45  0000
.421  34.697  -87.531   -9.52  -9.52  0000
.506  36.573  -88.429  -10.22 -10.22  0000
.491  37.099  -88.699  -10.62 -10.62  0000
.889  37.673  -89.865  -10.24 -10.24  0000
.500  39.220  -89.918  -10.87 -10.87  0000
.218  39.623  -91.050  -10.04 -10.04  0000
.902  40.040  -91.990   -8.52  -8.52  0000
```

Calibration

- Need to transform between pixel coordinates to az, el
- Every 30 minutes the camera computer produces a calibration plate (several images stacked together to show lots of stars)
- User runs an IDL script to match stars to image
- A least squares fit is performed to determine plate parameters

The transformation of the plate coordinates x, y to the celestial coordinates a, z is done by means of five equations. The equation for r can be rewritten as

$$r = C\left[\sqrt{(x-x_0)^2+(y-y_0)^2} + \right. \qquad (9)$$
$$\left. + A\,(y-y_0)\cos(F-a_0) - A\,(x-x_0)\sin(F-a_0)\right],$$

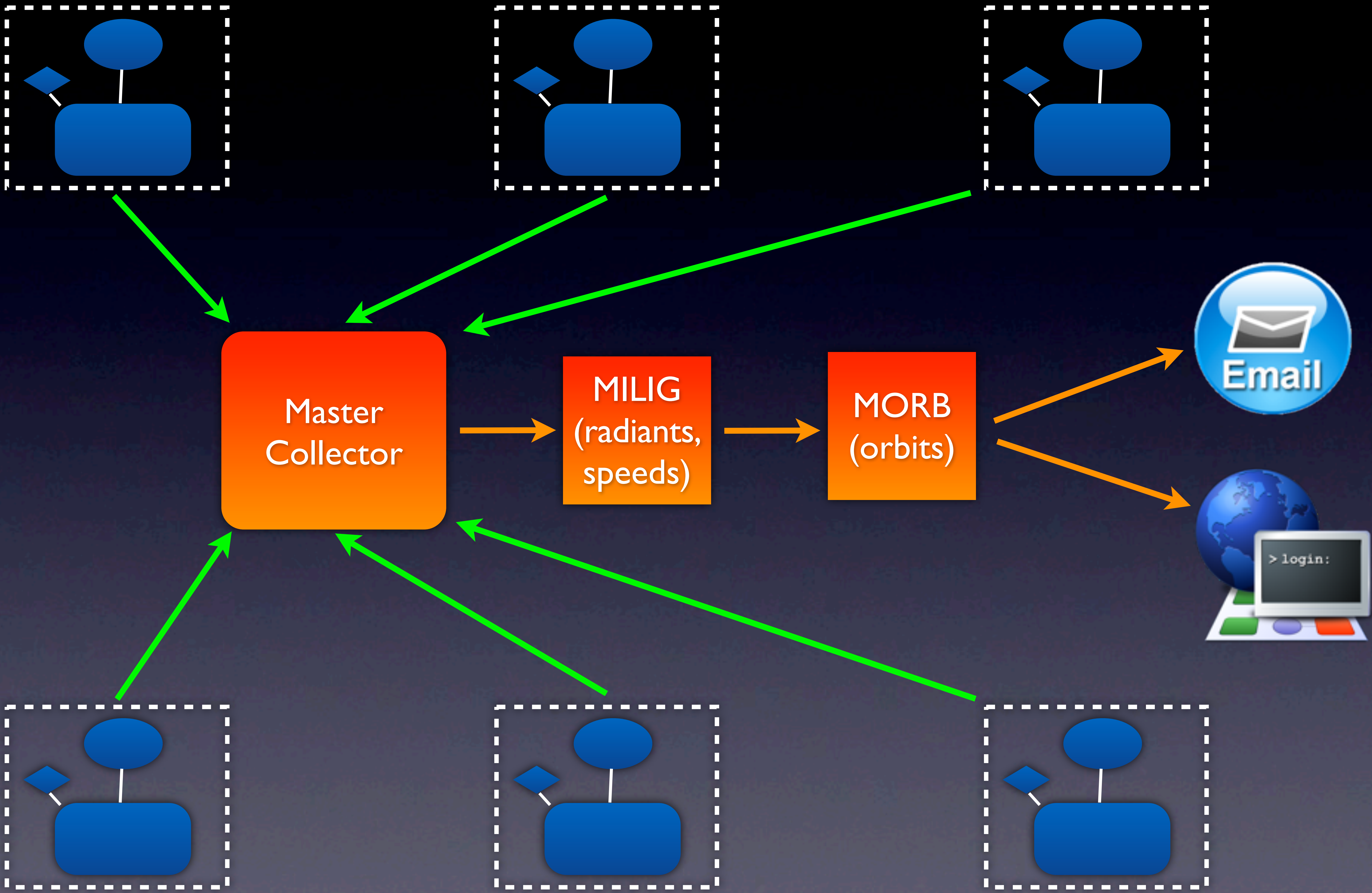
where we introduced the global scale factor C (see below). The other four equations are

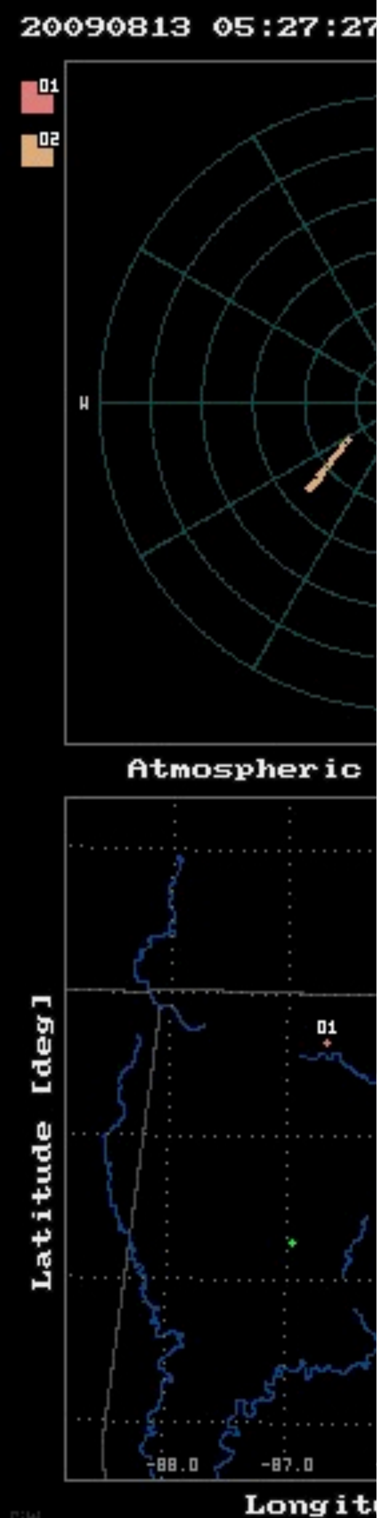
$$u = Vr + S(\mathrm{e}^{Dr}-1) + P(\mathrm{e}^{Qr^2}-1) \qquad (6)$$

$$b = a_0 - E + \arctan\left(\frac{y-y_0}{x-x_0}\right) \qquad (4)$$

$$\cos z = \cos u\,\cos\varepsilon - \sin u\,\sin\varepsilon\,\cos b \qquad (1)$$

$$\sin(a-E) = \sin b\,\sin u/\sin z \qquad (2)$$


Master Collector
MILIG (radiants, speeds)
MORB (orbits)
Email
> login:



From: "asgard (02)"
Date: August 13, 2009 6:03:52 AM CDT
To: "list"
Subject: **allsky 20090813**

Last sync and disk usage :

01 : 20090813 06:00:01 CDT : 280188 / 465365 MB free
02 : 20090813 07:00:02 EDT : 282305 / 465365 MB free

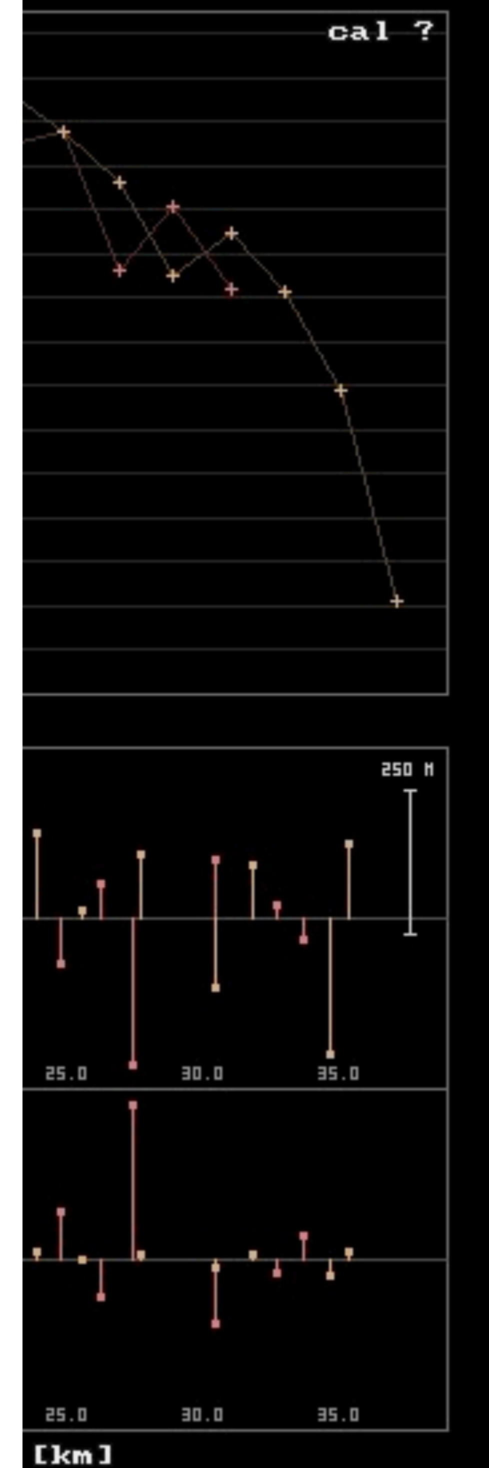
Last recorded event and plate :

01 : 20090813 100436 UTC : 20090724-094001-01-aut-calib-ID
02 : 20090813 102022 UTC : 20090724-094001-02-aut-calib-ID

ASGARD version and NTP status :

01 : 20090611 : LOCK 18154 64069 4032
02 : 20090611 : LOCK -13559 63498 7150

```
  date     time   :       : vel  beg   end  : src
------------------+-------+-----------------+-----
+ 20090813 03:16:41 : 01 02 : .... ..... ..... : ...
+ 20090813 04:01:55 : 01 02 : 59.7 109.8  99.5 : PER
+ 20090813 04:05:44 : 01 02 : 58.1 107.5  95.4 : PER
+ 20090813 04:10:46 : 01 02 : 58.0 103.4  93.5 : PER
+ 20090813 04:19:51 : 01 02 : 39.4  98.1  86.8 : ...
+ 20090813 04:25:20 : 01 02 : 60.4 109.8  90.7 : PER
+ 20090813 04:26:40 : 01 02 : 59.8 107.5  97.0 : PER
+ 20090813 04:38:54 : 01 02 : 60.5 109.6  95.5 : PER
+ 20090813 04:46:45 : 01 02 : 63.6 109.1  90.0 : PER
+ 20090813 05:04:44 : 01 02 : 58.8 106.9  89.6 : PER
+ 20090813 05:08:56 : 01 02 : 60.6 111.1  85.8 : PER
+ 20090813 05:09:33 : 01 02 : 60.5 102.5  92.1 : ...
```



Live View
20090615 E I
20090614 E I
20090613 E I
20090612 E I
20090611 E I
20090610 E I
20090609 E I
20090608 E I
20090607 E I
20090606 E I
20090605 E I
20090604 E I
20090603 E I
20090602 E I
20090601 E I
20090531 E I
20090530 E I
20090529 E I
20090528 E I
20090527 E I
20090526 E I

20090530 07:16:38 UTC ...
vel 24.5 km/s beg 82.3 km end 53.8 km
evcorr TXT PNG milig INPUT ZMILI ORBIT

20090530 07:29:17 UTC ...
vel 26.6 km/s beg 87.4 km end 58.2 km
evcorr TXT PNG milig INPUT ZMILI ORBIT

```
time 20090530 7.4881 hours
 lat  35 26 11.179 =  35.4364 deg
 lon 273 28 02.828 = 273.4675 deg
  ht 0.000 b 3.61297 -4.69162 -6.88988 -18.76613
      alp 253.822 +/-  0.084 deg
      del -10.430 +/-  0.171 deg
    v_inf  26.645 +/-  0.262 km/s
    v_avg  26.645 +/-  0.262 km/s

        a   2.292 +/-  0.076 AU
        e   0.771 +/-  0.009
     incl   8.245 +/-  0.208 deg
    omega 276.178 +/-  0.201 deg
 asc_node  68.911 +/-  0.000 deg
      v_g  24.325 +/-  0.288 km/s
      v_h  36.920 +/-  0.173 km/s
  alp_geo 251.922 +/-  0.090 deg
  del_geo -12.710 +/-  0.186 deg
    q_per   0.525 +/-  0.003 AU
    q_aph   4.059 +/-  0.154 AU
                     -  0.090 deg
                     -  0.186 deg
                     -  0.186 deg

                     201
                     eg
                     deg
                     g
```

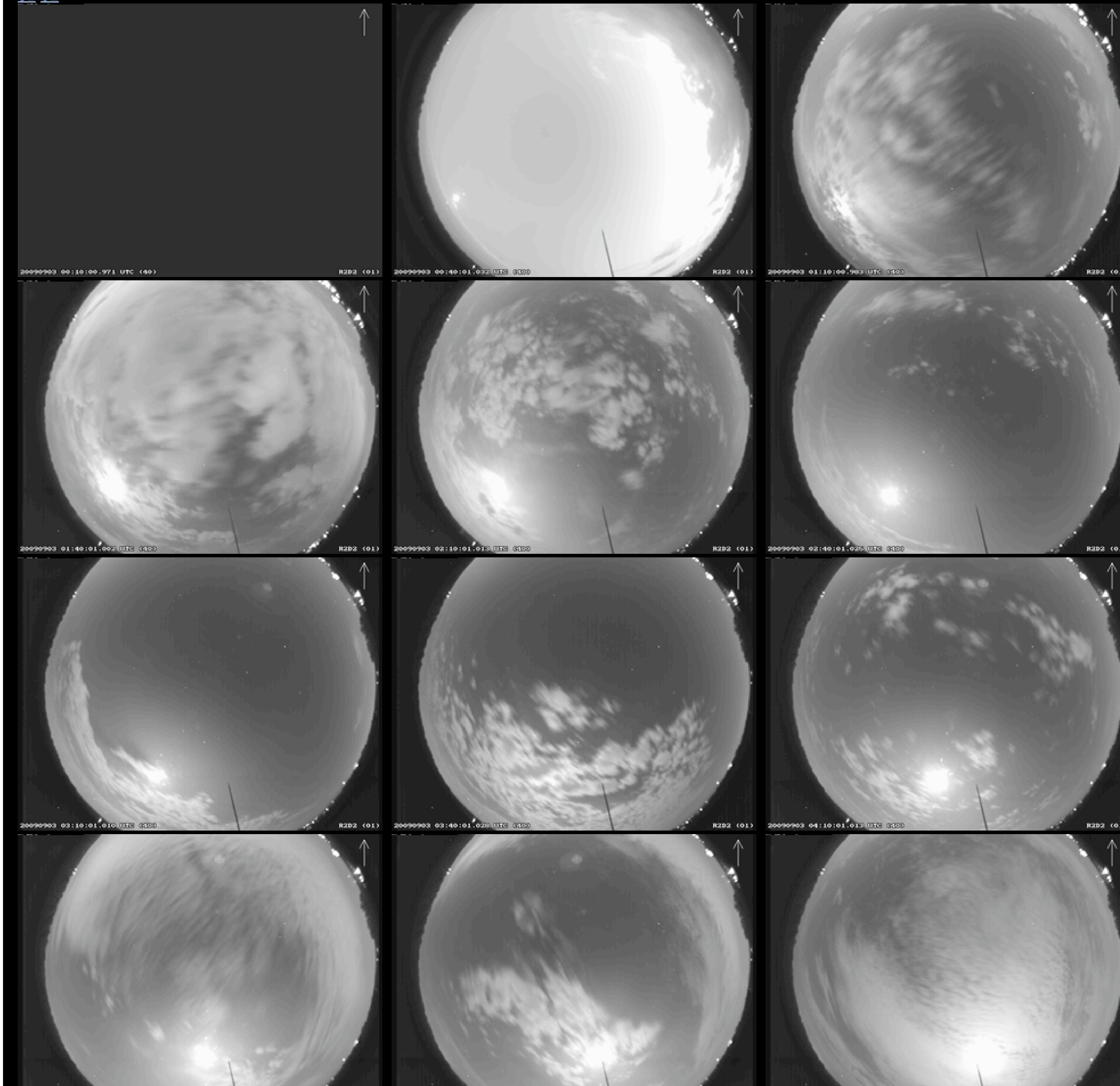
```
BEGINNING POINT:
                         X =    329.933   Y = -5281.118   Z =   3703.070
                                   .059            .011            .068
               GEOGRAPHIC     LAM =   -86.69515   FI =    35.16388   H =   87.381 KM
                                         .00063             .00078          .040

END POINT:
                         X =    342.215   Y = -5238.779   Z =   3711.185
                                   .052            .010            .058
               GEOGRAPHIC     LAM =   -86.53255   FI =    35.43644   H =   58.225 KM
                                         .00057             .00067          .034
 Note: LAMBDA approximate (valid for TIME=0)

 FOR THE END POINT:  AZIMUTH=   26.107   ZNT. DISTANCE=   49.577
                                  .131                      .162
```

Live View
20090903 E I
20090902 E I
20090901 E I
20090831 E I
20090830 E I
20090829 E I
20090828 E I
20090827 E I
20090826 E I
20090825 E I
20090824 E I
20090823 E I
20090822 E I
20090821 E I
20090820 E I
20090819 E I
20090818 E I
20090817 E I
20090816 E I
20090815 E I
20090814 E I

01 02



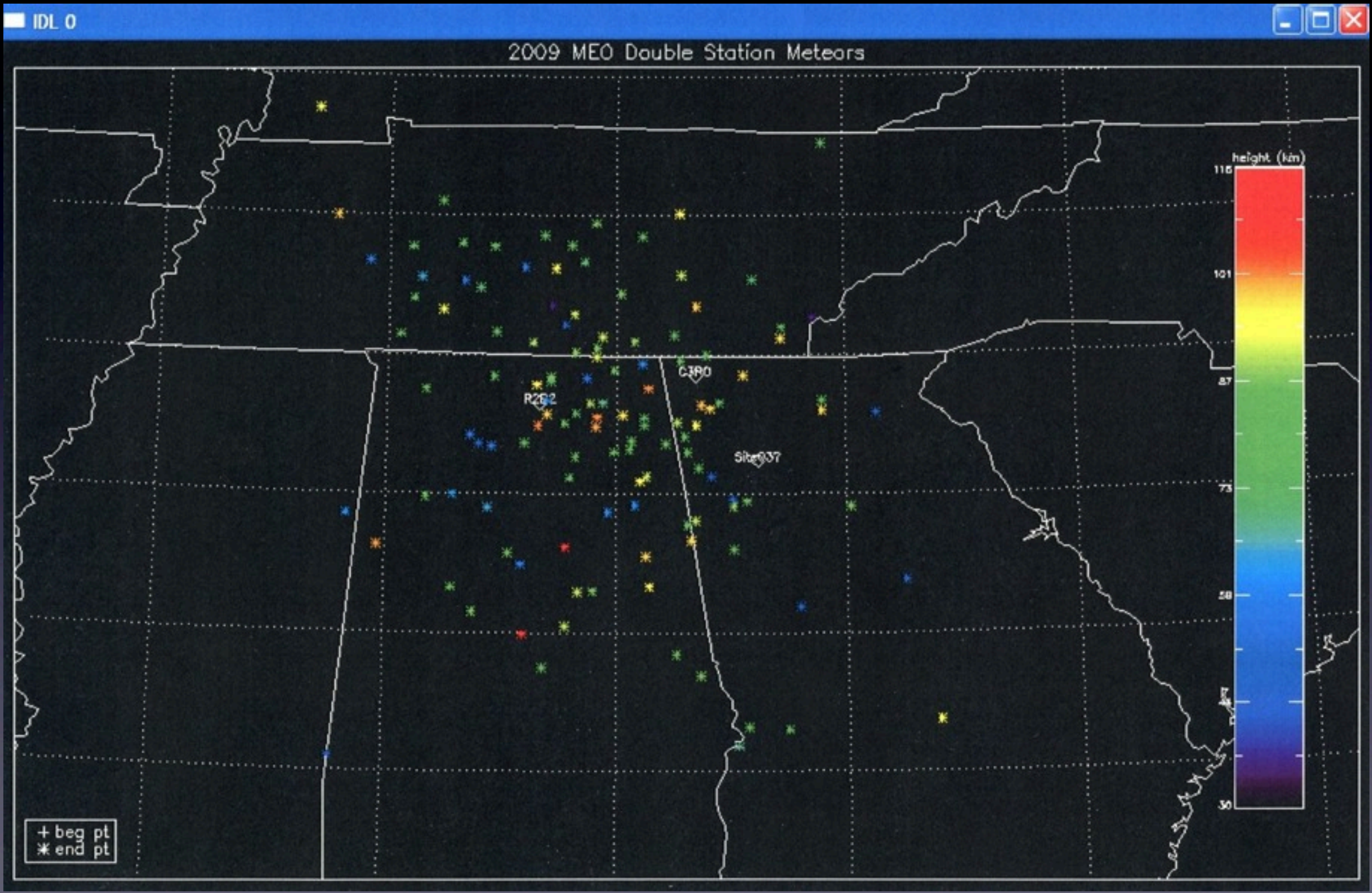
Sensitivity and Response

- Can detect magnitude 0 meteors
- ASGARD software can handle simultaneous events
- Aircraft (flashing lights) made detection algorithm crazy; continual improvements have reduced number of falses

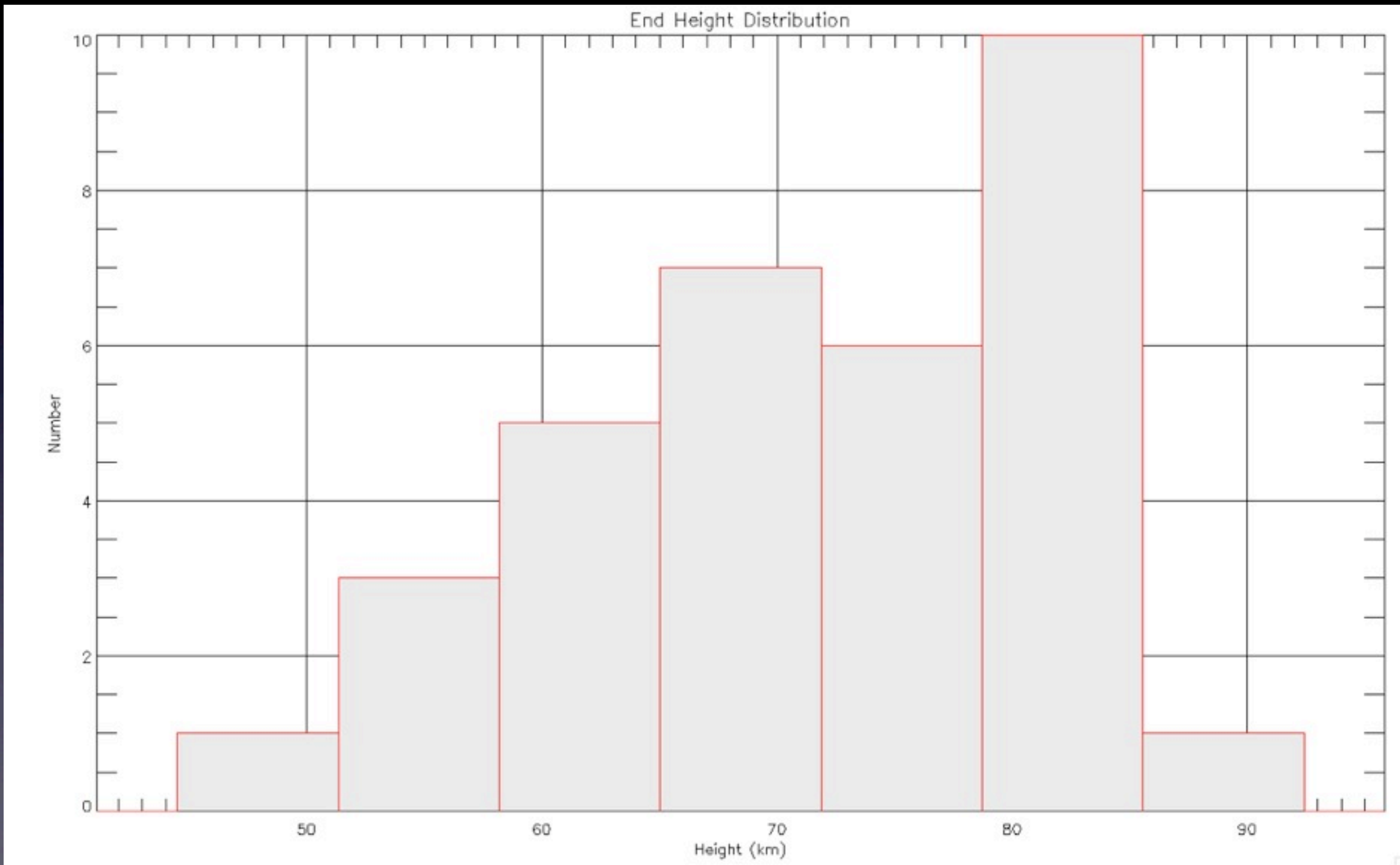
System Requirements

- ✓ Pentium 3, 900MHz, 512Mb RAM
- ✓ at least 40 Gb data space, in 2 partitions (>20 Gb for video buffer, rest to store events)
- ✓ US GlobalSat BU-353 Waterproof USB GPS units (required, available from http://www.gpscentral.ca/products/usglobalsat/bu353.htm)
- ✓ Brooktree 878A framegrabber (Hauppage WinTV card)
- ✓ Debian linux version 5
- ✓ DSL or faster internet connection

Coverage


IDL 0
2009 MEO Double Station Meteors
R2D2
C3PO
Site037
height (km)
115
101
87
73
58
30
+ beg pt
✳ end pt

Preliminary Geminid Results



2009 Perseids